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(12) # EUROPEAN PATENT APPLICATION

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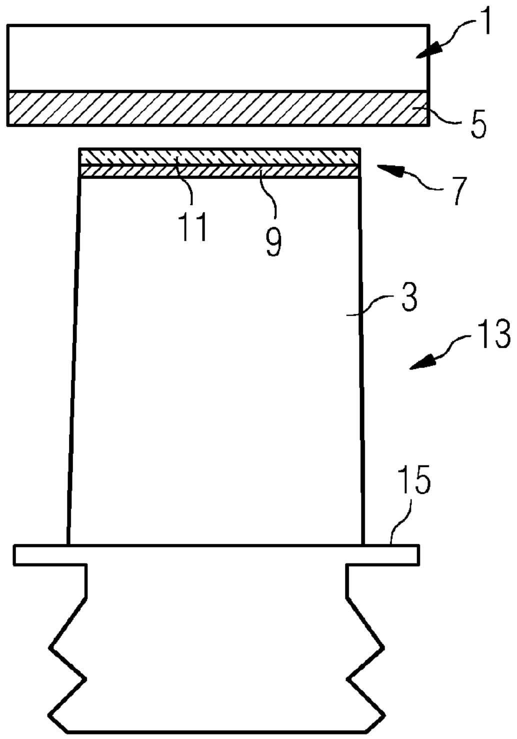
(71) Applicant: **SIEMENS AKTIENGESELLSCHAFT**
80333 München (DE)

(72) Inventors:
- **Li, Xin-Hai**
58272 Linköping (SE)
- **Carlsson, Peter**
60214 Norrkoping (SE)

(54) **Seal system for a gas turbine**

(57) An abradable seal system for a gas turbine comprises a rotor blade tip (7) with an abrasive coating system (9, 11) and a stationary heat shield ring (1) facing opposite to the blade tip (7) and coated with an abradable coating. The abrasive coating system comprises an oxidation resistant and/or corrosion resistant bond coat (9) and a thermal barrier coating (11) atop of the bond coat (9). The thermal barrier coating (11) is a ZrO_2 coating that is partially stabilized by Y_2O_3 and free of vertical macrocracks.

FIG 1



EP 2 540 973 A1

Description

[0001] The present invention relates to an seal system for a gas turbine which seal system comprises a rotor blade tip with an abrasive coating system and a stationary heat shield ring coated with an abradable coating and facing opposite to the tip.

[0002] Shroudless gas turbine blades are increasingly used in gas turbines. However, it is very difficult to find a good sealing method between such blade tips and heat shield segments above the tips to minimize the hot gas leakage and ensure the engine efficiency, especially, on the tips of 1^{st} and 2^{nd} stage blades where the temperature is high, i.e. about 1000°C or higher. It is often to observe that rubbing and oxidation damages on both the tips of the blades and the heat shield segments occur after a certain operating period. These damages increase the gap between the blade tips and the heat shield segments continuously, leading to an increased hot gas leakage thereby reducing the efficiency of the gas turbine.

[0003] EP 0 707 091 A1 describes a sealing system of gas turbines comprising a blade tip coated with a zirconium-based oxide having a plurality of vertical macrocracks. The zirconium-based oxide with the macrocracks shows good rub tolerance when contacting a seal ring of bare superalloy. The zirconium-based coating of EP 0 707 091 A1 is a zirconia coating with macrocracks where the zirconia is partially stabilized, by an amount of 6.5 to 9 weight percent yttria.

[0004] With respect to this prior art it is objective of the present invention to provide an advantageous seal system for a gas turbine. It is a further objective of the present invention to provide an advantageous gas turbine.

[0005] An inventive seal system for a gas turbine comprises a rotor blade tip with an abrasive coating system and a stationary heat shield ring located opposite to the blade tip. In particular, the heat shield ring may be formed by a number of ring segments together forming the seal ring.

[0006] The abrasive coating system on the blade tip comprises an oxidation resistant and/or corrosion resistant bond coat and a thermal barrier coating atop of the bond coat. The thermal barrier coating is a ZrO_2 coating that is partially stabilized by Y_2O_3 (abbreviated YSZ) and is free of macrocracks, at least of vertical macrocracks. The heart shield ring is coated with an abradable coating. In particular, the abradable coating may be a ceramic coating, for example a YSZ coating i.e., a coating of yttria stabilized zirconium oxide. In the context of the present invention, a crack is considered to be a macrocrack if its lengh is at least 0,1 mm.

[0007] When a gas turbine engine equipped with the invention seal system is started the thickness of both, the thermal barrier coating on the blade tip as well as the abradable coating will be abraded. Due to the rubbing of the blade tip a recess is formed in the abradable coating of the heat shield ring into which the tip projects so as to form some simple kind of labyrinth seal. Rubbing occurs in particular during start up because the blades extend their length due to thermal expansion. In full load operation when both the heat shield ring and the turbine blade will be at their maximum temperature, rubbing will eventually cease and the blade tip will project into the recess rubbed into the coating of the heat shield ring at a maximum depth. Due to a clearance that then exists between the abradable coating and the blade tip no rubbing will take place anymore. In this condition, the thermal barrier coating of the blade tip may be fully rubbed off. However, the oxidation resistant and/or corrosion resistant bond coat is still present to protect the tip. The clearance between the blade tip and the seal ring is small enough to provide a good sealing action. In that sense, the thermal barrier coating can be regarded as sacrificial coating on top of the bond coat.

[0008] The thermal barrier coating without macrocracks of the seal system is preferably a ZrO_2 coating that is partially stabilized by 5 to 9 wt% Y_2O_3, in particular by 7 wt% Y_2O_3. Moreover, the thermal barrier coating may be applied by air plasma spraying (APS) or by electron beam physical vapour deposition (EB-PVD).

[0009] The abrasive coating system, i.e. the bond coat and the thermal barrier coating, may be particularly applied only on the tip region of the blade, or it may be applied as an extension from the coating system of the airfoil, or as an extension from the coating system of the airfoil and the platform. Coating also other regions of the blade than the tip region with the abrasive coating system allows to coat the turbine blade in a single coating process. The abrasive coating system is not subject to rubbing except for the tip region so that the thermal barrier coating will not be rubbed off in the other regions of the blade.

[0010] In a further development of the invention, the thermal barrier coating has a porosity of more than 10% by volume. This measure helps to prevent the formation of macrocracks in the thermal barrier coating during applying the coating.

[0011] A suitable bond coat for the abrasive coating system is a so called MCrAlY-coating where M stands for cobalt (Co), nickel (Ni), or both of them, Cr stands for chromium, Al stands for aluminium and Y stands for yttrium and/or silicon (Si) and/or Hafnium (Hf) and/or at least one rare earth element.

[0012] According to a further aspect of the invention, a gas turbine is provided. The gas turbine comprises a rotor with one or more stages of rotor blades, a heat shield encasing at least one stage of rotor blades and an inventive seal system. In the inventive gas turbine, the heat shield segments are coated with the abradable coating to form the seal ring. The tips of the rotor blades encased by the heat shield segments are coated with the abrasive coating system. Typically, at least the first stage of rotor blades would be fitted with the seal system. However, further stages, in particular the second stage, can also be fitted with the seal system. The inventive gas turbine has only small leakage so that high efficiency of the gas turbine can be assured. Moreover, blade tip damages due to oxidation and/or corrosion can be reduced.

[0013] Further features, properties and advantages of the present invention will become clear from the following description of an embodiment in conjunction with the accompanying drawings.

Figure 1 schematically shows an inventive seal system.

Figure 2 shows the seal system of figure 1 after start of a gas turbine engine of which it is part.

Figure 3 shows the seal system of figure 1 after a while of full engine load operation.

[0014] In the following, the inventive seal system will be described with respect to figures 1 to 3. The seal system is part of a gas turbine with a rotor comprising a number of stages of turbine rotor blades arranged in axial direction of the rotor in alternating fashion with turbine nozzles. The stages of rotor blades are encased by annular heat shields composed of a number of heat shield segments. Typically, a stationary gas turbine has two to four stages of rotor blades and a corresponding number of vanes. However, a turbine may also have only one stage of turbine blades or even more than four stages. The gas turbine is equipped with an inventive seal system that comprises the tips of at least one of the stages of rotor blades and the respective heat shield.

[0015] Figure 1 schematically shows a heat shield segment 1 and a rotor blade 3. Other components of the gas turbine like, for example, the rotor to which the rotor blade 3 is fixed are not shown to keep the figure simple. The heat shield segment 1 is coated with an abradable coating 5 and represents a seal ring. In the present embodiment, the abradable coating is preferably a yttria stabilized zirconiumoxide coating (YSZ). On the tip 7 of the rotor blade 3, an abrasive coating system is present that comprises an oxidation resistant and/or corrosion resistant bond coat 9 and an overlying thermal barrier coating 11 that forms the top coat of the abrasive coating system.

[0016] In the present embodiment, a MCrAlY-coating is used as a bond coat 9, where M stands for iron, cobalt and/or nickel, Cr stands for chromium, Al stands for aluminium and Y stands for yttrium, hafnium, silicon or at least one rare earth element, or a combination thereof. The top coat of the abrasive coating system is, in present embodiment, zirconium oxide (ZrO_2) that is partially stabilized by 6 wt% yttrium oxide (Y_2O_3).

[0017] When the top coat is applied by air plasma spraying, the spraying parameters are used to avoid the formation of macrocracks, in particular the formation of vertical macrocracks. In other words, the parameters, when applying the YSZ-coating by air plasma spraying, are chosen such that only cracks occure that are shorter than 0.1 mm. Typical parameters that can be varied to achieve a macrocrack-free coating are temperature and velocity of the particles used in the spray process. Avoiding macrocracks can, for example, be achieved by setting the parameters in the air plasma spray process such that the applied YSZ-coating has a porosity larger that 10 % by volume. In this case, the formation of macrocracks is typically prevented.

[0018] Although the abrasive coating system is only shown on the tip of the rotor blade in figure 1 the coating system may be an extension of the coating system applied on the whole airfoil 13 and the platform 15 of the rotor blade 3 which are exposed to hot combustion gases during gas turbine operation.

[0019] Figure 1 shows the inventive seal system formed by the seal ring 1 with the abradable coating 5 and the blade tip 7 with the abrasive coating system composted of the MCrAlY-bond coat 9 and the YSZ-top coat 11 just after applying it.

[0020] Figure 2 shows the seal system after start of the gas turbine. In gas turbines, the rotor blades 3 are arranged with a tiny gap between the tips 7 of the rotor blades 3 and the encasing seal rings 1. Please note that in the figures the gap between the surface of the top coat 11 and the surface of the abradable coating 5 is exaggerated for clarity reasons. During start up operation of the gas turbine, an elongation of the turbine blades 3 occurs due to thermal expansion and centrifugal forces experienced by the blades 3 due to the rotation of the rotor. On the other hand, since the seal ring experiences no centrifugal force the diameter of the ring increases less than the length of the rotor blades. In addition, during start up of the gas turbine the thermal expansion of the rotor blades 3 and the seal ring 1 typically differ from each other. Both effects together lead to rubbing between the tips 7 and the seal ring 1. During this rubbing, a part of the abradable coating 5 is rubbed off by the abrasive coating system on the blade tip 7, in particular by the ceramic top coat 11. However, also the ceramic top coat is rubbed off so that its thickness will be reduced over time. After start up and a while of full load operation of the gas turbine the ceramic top coat 11 may be fully disappeared due to rubbing and due to lifetime limiting effects by bond coat oxidation in combination with thermal fatigue leading to spallation. However, the sealing is still ensured and the bond coat 9 will not be rubbed off due to a space 17 that has been generated by the ceramic top coat 11 abrading into the abradable coating 5. Hence, the bond coat 9 will still protect the blade tip 7 from high temperature oxidation and/or corrosion for the rest of the operation time.

[0021] The YSZ-coating on the blade tip 7 provides a better abradability at the high temperatures together with an abradable coating than a bare blade tip does. Moreover, the coated blade tip withstands a high temperature exposure up to 1200°C, and is even protected from oxidation and/or corrosion damages. Although the YSZ-layer 11 of the abrasive coating system may be fully rubbed off by abrading to the abradable coating of the seal ring or by spallation when it reaches its lifetime during gas turbine operation within an overhaul interval, the YSZ has already rubbed into the abradable coating with a maximum depth after a short time of full-load operation and, hence, fulfilled its function. In this sense, the YSZ-coating could be regarded as a sacrificial coating. The removal of the YSZ-coating has left a space between the bond coat surface and the rubbed surface of the abradable coating 5, so that the bond coat 9 will not or minimally be rubbed off in the later operation and can still protect the blade tip 7 from the oxidation.

[0022] The invention has been described with respect to an exemplary embodiment thereof as an illustrative example of the inventive seal system and the inventive gas turbine. However, please note that although a special embodiment has been described to explain the invention deviations from this embodiment are possible. For example, although the zirconium oxide was stabilized by 7 wt% yttrium oxide in the described embodiment the contend of yttrium oxide may vary between 5 wt% and 9 wt%. In addition, although an MCrAlY-coating has been described as bond coat other oxidation and/or corrosion resistant bond coats, in particular other alumina scale forming bond coats, may be used. Hence, the scope of the invention shall not be limited by the described exemplary embodiment but only by the appended claims.

Claims

1. A seal system for a gas turbine that comprises a rotor blade tip (7) with an abrasive coating system (9,11) and stationary heat shield ring (1) facing opposite to the blade tip (7), wherein the abrasive coating system (9,11) comprises an oxidation resistant and/or corrosion resistant bond coat (9) and a thermal barrier coating (11) atop of the bond coat (9) where the thermal barrier coating (11) is a ZrO_2 coating that is partially stabilized by Y_2O_3,
characterised in that

- the heat shield ring (1) is coated with an abradable coating (5), and
- the thermal barrier coating (11) is free of vertical macrocracks.

2. The seal system as claimed in claim 1,
characterised in that
the ZrO_2 coating (11) is partially stabilized by 5-9 wt% Y_2O_3.

3. The seal system as claimed in claim 1 or claim 2,
characterised in that
the abradable coating (5) is a ceramic coating.

4. The seal system as claimed in claim 3,
characterised in that
the ceramic abradable coating (5) is coating of yttria stabilized zirconium oxide.

5. The seal system as claimed in any of the claims 1 to 4,
characterised in that
the thermal barrier coating (11) is applied by air plasma spraying or electron beam vapour deposition.

6. The seal system as claimed in any of the claims 1 to 5,
characterised in that
the heat shield ring (1) is formed by a number of heat shield segments.

7. The seal system as claimed in any of the claims 1 to 6,
characterised in that
the abrasive coating system (9,11) is an extension from the coating system of the airfoil of the turbine blade (3).

8. The seal system as claimed in any of the claims 1 to 7,
characterised in that
the thermal barrier coating (11) has a porosity of more than 10% by volume.

9. The seal system as claimed in any of the claims 1 to 8,
characterised in that
the bond coat (9) is a MCrAlY-coating.

10. A gas turbine comprising a rotor with one or more stages of rotor blades (3), a heat shield ring (1) encasing at least one stage of rotor blades (3) and a seal system as claimed in any of the claims 1 to 8,
characterised in that
the heat shield ring (1) is coated with the abradable coating (5) and the tips (7) of the rotor blades (3) encased by the heat shield (1) are coated with the abrasive coating system (9,11).

FIG 1

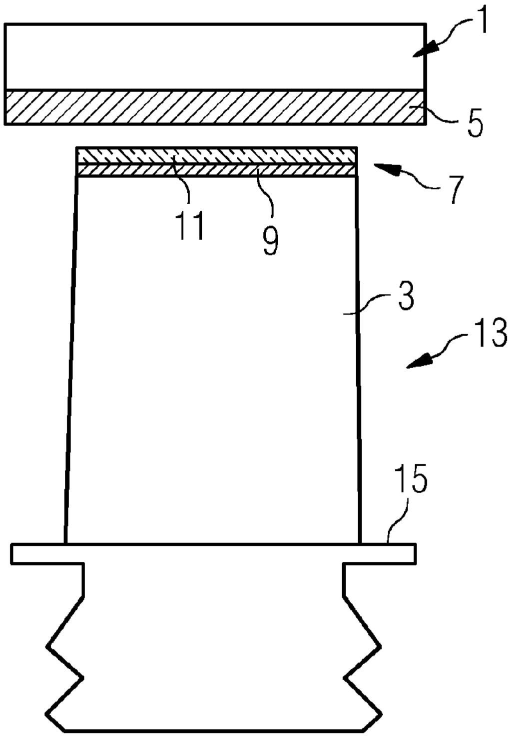


FIG 2

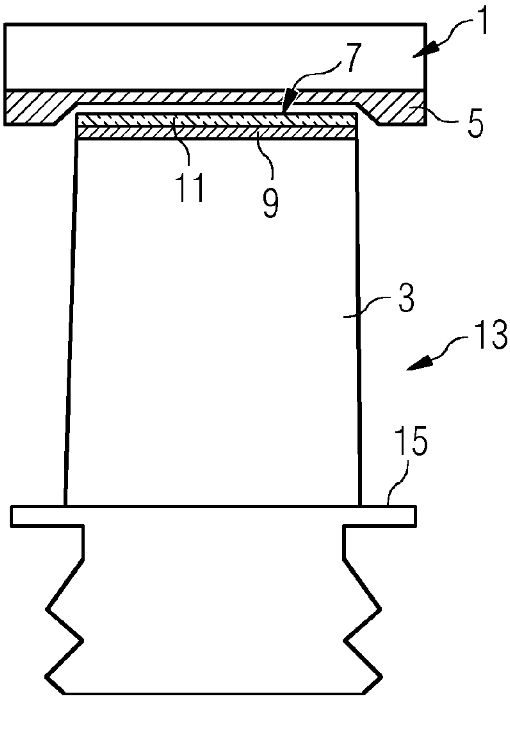
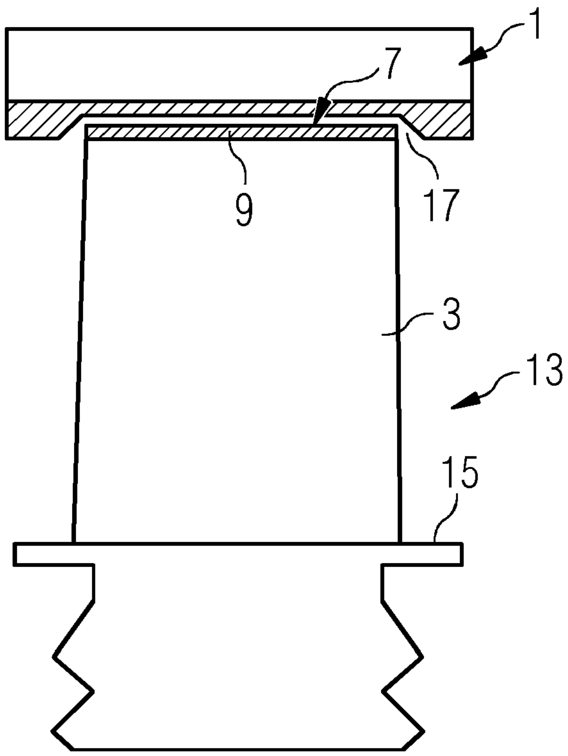


FIG 3



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EUROPEAN SEARCH REPORT

Application Number
EP 11 17 2105

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2003/138658 A1 (TAYLOR THOMAS ALAN [US] ET AL) 24 July 2003 (2003-07-24) * paragraphs [0013], [0027] - [0036] * -----	1-10	INV. F01D5/20 F01D5/28 F01D11/12 C23C28/00
Y	EP 2 192 098 A2 (ROLLS ROYCE CORP [US]) 2 June 2010 (2010-06-02) * paragraphs [0057] - [0071]; figures 6,7 * -----	1-10	
Y	WO 2011/019486 A1 (PRAXAIR TECHNOLOGY INC [US]; TAYLOR THOMAS ALAN [US]) 17 February 2011 (2011-02-17) * paragraphs [0051] - [0054] * -----	1-10	
			TECHNICAL FIELDS SEARCHED (IPC)
			F01D C23C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	29 November 2011	Oechsner de Coninck

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29-11-2011

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003138658 A1	24-07-2003	BR 0307051 A	11-04-2006
		CA 2473889 A1	31-07-2003
		CN 1642734 A	20-07-2005
		EP 1467859 A1	20-10-2004
		JP 4250083 B2	08-04-2009
		JP 2006503722 A	02-02-2006
		MX PA04007072 A	29-10-2004
		SG 152911 A1	29-06-2009
		US 2003138658 A1	24-07-2003
		WO 03061961 A1	31-07-2003
EP 2192098 A2	02-06-2010	CA 2686332 A1	25-05-2010
		EP 2192098 A2	02-06-2010
		US 2010129636 A1	27-05-2010
WO 2011019486 A1	17-02-2011	US 2011171488 A1	14-07-2011
		WO 2011019486 A1	17-02-2011

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- EP 0707091 A1 **[0003]**